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Alexandra Juphard, Serge Carbonnel, Bernard Ans and Sylviane Valdois

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Length effect in naming and lexical decision: the multitrace memory model's account.

Alexandra Juphard, Serge Carbonnel, Bernard Ans and Sylviane Valdois

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INTRODUCTION

Several studies have shown that length had no effect on naming latency for words but was significantly related to naming latency for pseudo-words (Ans, Carbonnel, & Valdois, 1998; Baciu, *et al.*, 2001; Juphard, Carbonnel, & Valdois, 2004; Valdois, Carbonnel, Juphard, Baciu, Ans, Peyrin & Segebarth, in press). Other studies reported a length effect for low-frequency words but not for frequent real words (Ferrand, 2000; Weekes, 1997; Jared, & Seidenberg, 1990). In line with these previous findings, Juphard and colleagues (2004; also Valdois et al., 2006) showed that naming latencies were similar for words of one, two and three syllables whereas they significantly increased with length for pseudo-words. Similarly, Ferrand (2000) found longer naming latencies for three than for two syllables pseudo-words but also reported length effects for low frequency words. Naming latencies for high frequency words alone were not affected by increasing length.

In these two latter studies, results were interpreted in the framework of the multiple-trace connectionist memory model of polysyllabic word reading (Ans, *et al.*, 1998; ACV98 hereafter). In this model, a single mechanism underlies word and pseudo-word reading, through two reading procedures, a global and an analytic one. These procedures are assumed to work serially, the global procedure always proceeding first before any involvement of the analytic procedure. An essential feature of the model is the postulate of a visual attentional window (VAW) through which information from the orthographic input is extracted. The two reading procedures differ in the size of the VAW involved. In global reading mode, the VAW extends over the whole sequence of the input letter-string. When shifting in analytic mode, the VAW narrows down to focus attention on the first part of the orthographic input. Analytic processing then proceeds through a narrow VAW which shifts from left to right, focalising attention on the different parts of the input successively. Analytic processing thus implies a number of successive visual attentional captures depending on the length of the input letter-string. Simulations run on the ACV98 network (Ans *et al.*, 1998) have shown that most known words are processed globally whereas most unfamiliar letter strings (novel words and pseudo-words) are processed analytically, syllable by syllable. Consequently, a length effect on naming latencies is expected for pseudo-words in reading whereas familiar words which are globally processed whatever their length should yield no length effect in naming.

Very similar predictions on length effects follow from the dual-route cascaded model (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001; DRC hereafter). This model assumes the existence of two routes, a lexical and a phonological one, running in parallel to convert print to sound. The former allows direct access to word pronunciation and meaning *via* lexicons built during reading acquisition while the second is thought to be based on a grapheme to phoneme conversion (GPC) procedure that applies serially on letter strings from left to right (Coltheart & Rastle, 1994; Kwantes, & Mewhort, 1999; Monsell, Patterson, Graham, Hughes, & Milroy, 1992). When operating in isolation, the lexical route can only produce the correct pronunciation of known words whereas the phonological route can produce the correct pronunciation of both pseudo-words and words that obey the GPC rules. As the lexical route is hypothesized to operate faster than the phonological route and because word access is insensitive to length, naming latency is expected not to be affected by word length. On the contrary, naming latency is expected to increase proportionally to pseudo-word length as processing by the phonological route is serial. In sum, this second class of models also predicts a length effect restricted to pseudo-words in reading.

At the opposite, Parallel Distributed Processing (PDP) models of reading (Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg & Patterson, 1996; PMSP 96 hereafter; Seidenberg & McClelland, 1989) do not *a priori* predict any interaction between length and lexicality in reading. Indeed, they assume that both words and pseudo-words are read globally in a single uniform system, based on knowledge of the orthography-to-phonology correspondences of familiar words. As words and pseudo-words are similarly processed, a length effect if occurring should not differ according to lexicality.

The present research aimed at investigating length effect according to lexicality, not only in reading aloud but also in lexical decision. Comparatively to the naming task, very few studies investigated the effect of length in lexical decision. Using items of one-, two- and three-syllables, Juphard and colleagues (2004; see also Valdois et al., 2006) found no length effect for either words or pseudo-words in lexical decision. Such a result is in total agreement with the ACV98 model. Indeed, within this framework, lexical decision depends on the characteristics of the orthographic echo generated at the end of global processing, thus before any shifting in analytic mode. Since lexical decision always and only follows from global processing, no length effect is expected whatever the item's lexicality. Similarly, no length effect is expected in lexical decision within the dual route framework. Indeed, dual route models postulate that accurate lexical decision can be made on the basis of the orthographic lexicon overall level of activation (Coltheart *et al.*, 2001); and lexical activation is not sensitive to input length. With respect to PDP models, no differential length effect should affect lexical decision latencies for words and pseudo-words since both types of items are processed globally by the same mechanism.

Ferrand and New (2003) investigated syllable length effects in both naming and lexical decision. Replicating Ferrand's findings (2000), they found a length effect in naming for pseudo-words and low-frequency words. However and contrary to the ACV98 model's predictions, they also reported a syllable length effect in lexical decision for low-frequency words only.

Because empirical evidence on length effect in lexical decision remains unclear, the present research reinvestigates length effects for words and pseudo-words in both naming and lexical decision. It further extends previous findings in investigating longer items, from 2 to 4 syllables. The first experiment required to name, or to make a lexical decision on words and pseudo-words of two, three and four syllables. A control experiment of delayed naming was additionally conducted on the same items in order to ensure that length effects were actually due to processing time rather than to articulatory output generation as previously suggested (Seidenberg, & Plaut, 1998). Finally, simulations on the ACV98 network were run on the same items in reading and lexical decision to allow direct comparison with the behavioural data.

EXPERIMENT 1: Naming and lexical decisionMethodParticipants

Forty undergraduate psychology students from the University of Savoie participated in the experiment for a course credit. All participants in this and the following experiments were native French speakers and reported normal or corrected-to-normal vision.

Material

The experimental items consisted of 60 words and 60 pronounceable pseudo-words. In each lexical category, a third of items was either two-syllable, three-syllable or four-syllable long. The words were selected from the French data base "BRULEX" (Content, Mousty, & Radeau, 1990). They were from low to medium logarithmic frequency (*mean log frequency* = 3.31; *standard deviation* = 0.62; *range* = 1.67 - 4.65). Word frequency minimally differed in the three sets of 2-, 3- and 4 syllable words (m = 360.1, SD = 56.6; m = 323.4, SD = 54.9; m = 309.3, SD = 63.9 respectively; $F(2,57)=3.82$, $p=.03$). Half of the experimental words (10 out of 20) ended with a final mute "e" in each syllable length. The 60 experimental pseudo-words were created by recombining the syllables of the target words with the constraint that the relative syllable position remained unchanged (e.g, the pseudo-word "pansor" was generated using the first syllable of the word "pantalon" and the second syllable of the word "trésor"). Furthermore, the experimental words and pseudo-words were matched for bigram and trigram frequencies for each position (initial, middle and final). As for the experimental words, half pseudo-words ended with a mute "e" in each length set. The experimental words and pseudo-words of each syllable length were further matched for their number of letters (mean number of letters and range for each syllable length: m = 5.5, 4-6 letters for 2-syllable items, m = 7.4, 6-8 letters for 3-syllable items and m = 9.2, 8-10 letters for 4-syllable items). All experimental items began with a stop consonant (/k/, /d/, /g/, /p/, /t/, or /b/) in order to trigger the voice key as soon as the participants started pronouncing the input item in the reading task. Two sets of 36 filler words and pseudo-words, half ending with a mute "e" were mixed with the experimental items. They had a mean log frequency of 3.61 and began with either a vowel or a non stop consonant. The 36 filler pseudo-words were created from the filler words, in the same way as the experimental pseudo-words. The complete list of stimuli is given in Appendix A. It further included 36 practice items (18 words and 18 pseudo-words).

Procedure

The experiment was controlled by the E-prime software. Since the same stimuli were used in the two experimental tasks (reading aloud and lexical decision), the nature of the task was a between-participant factor. Accordingly, the participants were randomly assigned to one of the two tasks at the beginning of each experimental session. They sat at 50 cm of the computer monitor. The stimuli were displayed in lowercase letters (bold Courier New 22) in the centre of a 19'' PC colour monitor. They were presented in black on a white screen. Their angular size varied from 3.7° to 6.7° for the 2-syllable items, from 6.1° to 8° for the 3-syllable items and from 8.1° to 10.2° for the 4-syllable items.

In the naming task, the participants were instructed to read each item aloud as accurately and as quickly as possible. Each trial began by a fixation point centred on the screen for 500 ms, followed by a white screen for 150 ms before the item presentation. The stimuli (word or pseudo-word) were presented one at a time and disappeared when the participant began to speak into the microphone connected to a voice key, or after 2000 ms when no response was given. The computer clock timed response latencies from the appearance of the stimulus to the onset of the participant's response. After the participant's response, a second white screen was displayed for 1000 ms before the next trial. It allowed the experimenter to record naming accuracy on the keyboard.

In the lexical decision task, the experimental procedure was the same, except that the software automatically recorded response accuracy together with reaction times. The participants had to decide as quickly and as accurately as possible whether the printed item was a real word or not by pressing keyboard buttons (response YES, right hand, key ","; response NO, left hand, key "w").

In both tasks, the items were presented in two equivalent sub-lists in order to allow the participants to have a rest. Presentation order of the two lists was counterbalanced in a randomised way along participants, in such a manner that half of them began the session with the first sub-list and the other half with the other sub-list. Each sub-list began with 18 practice items (9 words mixed to 9 pseudo-words of each syllable length), followed by 96 items including 60 experimental items (30 words and 30 pseudo-words of two, three and four syllables) and 36 fillers (18 words and 18 pseudo-words of two, three and four syllables). Two randomised orders of trial presentation were further designed for both tasks. Half participants were submitted to one trial order, the other half to the other order.

Results

Reaction times (RTs) longer than 1500 ms or shorter than 300 ms were discarded from the analyses (0.5%) together with the items (N=7) yielding less than 75% accuracy.

Mean reaction times (RTs) and error rates by participants (*F*1) and by items (*F*2) were analysed by 2 X 2 X 3 ANOVAs. Task (naming or lexical decision) was a no repeated measure factor in the analysis by participants (*F*1), while Lexicality (words or pseudo-words) and Length (two, three or four syllables) were within-participant factors. In the by-items analysis (*F*2), Task was the within-item factor whereas Lexicality and Length were the no repeated measure factors. Mean reaction times, standard deviations and error rates in each condition are presented in Table 1.

Table 1. Mean Reaction Times in milliseconds (RT), mean Error Rates (*ER*) and (*standard deviations)* according to lexicality (word and pseudo-word) and length (2, 3 or 4 syllables) in naming and lexical decision tasks.

		Words			Pseudo-words		
		2 syllables	3 syllables	4 syllables	2 syllables	3 syllables	4 syllables
Reading	RT	520.5 (63.5)	521.6 (60.8)	546.6 (72.7)	568.7 (84.4)	653.3 (110.8)	773.5 (152.7)
	ER	6.2 (6.6)	4.1 (5.9)	7.4 (7.2)	3.5 (5.4)	7.9 (5.7)	11.2 (7.9)
Lexical Decision	RT	577.8 (63.2)	580.3 (71.3)	596.7 (69.3)	648 (81.9)	640.4 (92.3)	669.2 (126.2)
	ER	1.2 (3)	1.2 (2.4)	0.9 (2.1)	3.5 (4.3)	0.6 (1.8)	0 (0)

Reaction Time Analyses

The main lexicality [$F1(1,38)=109.5$, $p<.001$; $F2(1,96)=277.0$, $p<.001$] and length effects [$F1(2,76)=60.76$, $p<.001$; $F2(2,96)=41.92$, $p<.001$] were significant. The main effect of task was only significant by items [$F1<1$; $F2(1,96)=12.14$, $p<.001$]. Moreover and more interestingly, the Lexicality by Length by Task second order interaction was significant [$F1(2,76)=26.68$, $p<.001$; $F2(2,96)=20.14$, $p<.001$] reflecting a significant Length by Task interaction for the pseudo-words only [$F1(2,76)=33.21$, $p<.001$; $F2(2,96)=44.87$, p<.001; both Fs<1 for words]. Planned comparisons were conducted to analyse the Length by Task interaction in each task separately.

In reading, performance was characterised by a main lexicality effect on naming latencies [$F1(1,38)=97.43$, $p<.001$; $F2(1,96)=179.77$, $p<.001$]: mean RTs were 135.6 ms slower for words (529.6 ms) than pseudo-words (665.2 ms). The analysis further revealed a main Length effect [$F1(2,76)=85.51$, $p<.001$; $F2(2,96)=43.61$, $p<.001$] and a significant length by Lexicality interaction [$F1(2,76)=54.76$, $p<.001$; $F2(2,96)=24.31$, $p<.001$]. Length effect was significant for words in the by-participants analysis only [$F1(2,76)=8.46$, $p<.001$; $F2(2,96)=1.62$, ns]. A slight but significant difference in mean RTs was found between 3 and 4-syllable words [difference=25ms, $F1(1,38)=10.74$, $p<.003$] but not between 2 and 3 syllable words [$F1<1$]. In contrast, the analyses revealed a strong and significant pseudo-word length effect [$F1(2,76)=83.45$, $p<.001$; $F2(2,96)=66.3$, $p<.001$]: 4-syllable pseudo-words were read more slowly than 3 syllable pseudo-words [difference= 120.2 ms, $F1(1,38)=55.19$, $p<.001$; $F2(1,96)=47.12$, $p<.001$] which in turn were read more slowly than 2 syllable pseudo-words [difference=84.6 ms , $F1(1,38)=76.19$, $p<.001$; $F2(1,96)=20.93$, $p<.001$].

The main effects of lexicality [$F1(1,38)=24.27$, p<.001; $F2(1,96)=131.47$, p<.001] and Length [$F1(2,76)=3.84$, p<.03; $F2(2,96)=5.05$, p<.009] were also significant in lexical decision: mean RTs were 67.7 ms slower for words (584.9 ms) than pseudo-words (652.6 ms); Lexical decision latencies on four-syllable items were slightly longer than on 3 syllable items (difference= 22.5 ms) which were in turn processed as quickly as 2 syllable items. However contrary to reading, the Lexicality by Length interaction was not significant [both Fs<1].

Error Analyses

The raw error scores were analysed by ANOVAs using the same factors as in the RT analyses. In naming, the effect of lexicality was significant in the by participants analysis only [$F1(1,38)=4.06$, $p=.05$; $F2(1,96)=1.65$, ns] with a higher error rate for pseudo-words (7.55%) than for words (5.88%). A main length effect was found [$F1(2, 76)=11.57$, $p<.001$; $F2(2,96)=4.14$, $p<.02$] and the Lexicality by Length interaction was significant in the by participants analysis [$F1(2,76)=4.14$, $p<.02$; $F2(2,96)=2.77$, ns], showing a significant Length effect for pseudo-words only [$F1(2,76)=10.52$, $p<.001$; $F2(2,96)=5.85$, $p<.005$].

The analyses revealed a main Length effect in the by-items analysis only but no Lexicality effects on error scores in lexical decision [$F1(2, 76)=2.22$, ns; $F2(2,96)=3.86$, $p<.03$ and $F1<1$; $F2<1$ respectively]. The Lexicality by Length interaction [$F1<1$; $F2(2,96)=3.08$, $p=.05$] and the pseudo-word length effect [$F1(2,76)=2.55$, ns; $F2(2,96)=6.89$, $p<.002$] were significant in the by-items analysis only. Overall, the error pattern was in no way the reverse of the RTs pattern in either task, thus showing the absence of speed-error trade-off effect between RTs and error rates.

In sum, the present findings show that Length effects on naming latency differ according to Lexicality. A strong Length effect on naming latencies was found for pseudo-words. In contrast, performance was similar for 2 and 3 syllable words and RTs were only slightly longer for four-syllable words as compared to three-syllable words. The significant Length by Lexicality interaction in naming supports the hypothesis that word and pseudo-word reading does not rely on the same mechanism. In contrast, the absence of significant Length by Lexicality interaction in lexical decision suggests that words and pseudo-words were similarly processed in this task.

These assumptions are further supported by the significant Length x Lexicality x Task second order interaction. The absence of Length by Task interaction for words conforms to the assumption that words are similarly processed in both tasks. In contrast, the significant interaction found for pseudo-words suggests that pseudo-word processing relies on different mechanisms in naming and lexical decision.

However, the length effect on pseudo-word naming latency found in Experiment 1 might also be due to peripheral components of the reading system, like articulatory processes. A delayed naming task in which participants were asked to pronounce the printed items on presentation of a cue after a time interval was used to discard this hypothesis. In delayed naming, the spelling-to-sound conversion process is supposed to complete before the participants start pronouncing so that latency primarily reflects the articulatory execution stage. Accordingly, length effects should remain if they were mainly due to articulation but they should disappear if they rather reflected time needed to generate a phonological output.

EXPERIMENT 2: Delayed namingMethodParticipants

Sixteen undergraduate psychology students from the University of Savoie participated in the experiment for a course credit. None of them had participated to Experiment 1.

Materials

Stimuli were the same as in Experiment 1.

Procedure

The procedure was nearly identical to the online naming task of Experiment 1, except that the participants had to wait until the appearance of a response cue before naming the input letter-string, as quickly and as accurately as possible. The response cue consisted in a rectangle that was displayed 200 ms after the disappearance of the to-be-named stimulus, and remained on the screen until the participant's response. The target items were presented for 1200 ms. Presentation time of the filler items was varied (800 ms, 1000 ms or 1200 ms) in order to prevent the participants from anticipating the response cue. Response latencies in milliseconds were computed from the appearance of the cue to the onset of participant's response.

Results

Items (0.83%) yielding more than 25% of errors were removed from the analyses. Mean reaction times by participant (*F*1) and by items (*F*2) were analysed by ANOVAs, including the Lexicality (word, pseudo-word) and Length (two, three or four syllables) factors. In the by-participants analysis (*F*1), Lexicality and Length were within-participant factors whereas they were no repeated measure factors in the by-items analysis (*F*2). Mean reaction times and error rates are presented in Table 2 for each condition.

Table 2. Mean Reaction Times in milliseconds (RT), mean Error Rates (*ER*) and (*standard deviations)* according to lexicality (word and pseudo-word) and length (2, 3 or 4 syllables) in the delayed naming task.

	Words			Pseudo-words		
	2 syllables	3 syllables	4 syllables	2 syllables	3 syllables	4 syllables
RT	392.7 (57.1)	378.5 (42.6)	388.4 (54.4)	407.8 (69.4)	414 (66)	423 (79.5)
ER	4 (6.3)	3.3 (4.9)	2 (3.7)	3 (4.2)	3.3 (4.5)	5.3 (6.5)

There was no significant Length by Lexicality interaction [$F1(2,30)=2.11$, ns; $F2(2,108)=1.13$, ns] in the delayed naming task but only a main Lexicality effect [$F1(1,15)=10.06$, $p<.007$; $F2(1,108)=18.22$, $p<.001$]. Mean RTs were 28.4 ms shorter for words (386.5 ms) than for pseudo-words (414.9 ms). The error analyses revealed no other significant main effect or interaction (All Fs inferior or close to1).

These last findings show the absence of any length effect when naming is delayed. Although a significant lexicality effect remained, the difference in RTs between words and pseudo-words was far smaller than in Experiment 1 for both online naming and lexical decision (28.4 ms in delayed naming against 135.6 ms in online naming and 67.7 ms in lexical decision). Furthermore, an additional 2X3X2 ANOVA with Lexicality (words vs. pseudo-words) and Length (two, three or four syllables) as between-item factors and Condition of naming (online vs. delayed) as within-item factor was conducted on the items of Experiments 1 and 2. The analysis revealed a significant Lexicality by Condition interaction [$F(1,90)=145.93$, $p<.001$], suggesting that Lexicality effects reflected different processes in the two naming conditions. The slight lexicality effect found in delayed naming would mainly reflect differences in articulatory programming due to the necessity to compute a new program for unfamiliar items (*i.*e, pseudo-words) but not for familiar ones (*i.*e, words). The stronger lexicality effect found in online naming would also partly reflect differences in articulatory processing but it would mainly result from differences in the reading procedures involved in word and pseudo-word naming.

SIMULATIONS

Simulations were conducted on the ACV98 network in both reading and lexical decision. Time needed to clean up the noisiest phonological cluster was used as an indicator of word naming latency, as in the previous simulations reported by Ans, Carbonnel & Valdois (1998) or Valdois et al. (in press). Pseudo-word naming latencies could not be estimated using the same indicator as for real words since pseudo-word latencies mainly reflect the number of attentional captures required for analytic processing to be completed. Thus and following Plaut (1998), the number of attentional captures required to generate a correct pronunciation was taken as the most appropriate estimation of pseudo-word naming latencies.

With respect to lexical decision, the indicator of reaction times was the same as the indicator of word naming latency except that time to clean-up was estimated at the output orthographic level. As for phonological responses, the output orthographic echo has to be entirely stabilized (i.e., all the clusters have to be clean) before a comparison can be made between the orthographic input and the orthographic output. It was assumed that response latency was determined by the orthographic cluster which had the longest clean-up time. As in previous experiments, an item was accepted as a real word whenever the orthographic echo was strictly identical to the orthographic input; it was rejected otherwise. The simulation was run on the set of 60 words and 60 pseudo-words used in Experiments 1 and 2. Results are presented in Table 3.

All items were read accurately by the network, except one 2-syllable pseudo-word that was removed from the analyses. Seven additional items (one word of each syllable length, one pseudo-word of 2 and 3 syllables and two 4-syllable pseudo-words) yielding a simulated naming latency or a number of visual attentional captures higher than two standard deviations of the network mean performance for each experimental condition were also discarded from the analyses.

Two separate ANOVAs, one for each type of items (words and pseudo-words), were done with Length (two, three and four syllables) as a between-item factor. They revealed a significant Length effect for the pseudo-words only [$F(2, 51)=75.73$, $p<.001$; for words $F<1$].

Table 3. Latency estimation for words and pseudo-words in reading (mean phonological cleaning time *PCT and SD*, and mean number of visual attentional captures *NVAC and SD*, respectively) and lexical decision (mean orthographic cleaning time *OCT, SD*), according to length.

		Words			Pseudo-words		
		2 syllables	3 syllables	4 syllables	2 syllables	3 syllables	4 syllables
Reading	PCT	7.9 (5.7)	6.4 (3.8)	7.1 (4.9)			
	NVAC				2.3 (0.99)	4 (0)	5 (0)
Lexical Decision	OCT	7.4 (5.4)	7.4 (2.7)	7.6 (5.8)	31.1 (9.5)	32.9 (11.3)	32.2 (11.6)

With respect to lexical decision, The network erroneously recognised eight two-syllab

le pseudo-words as familiar words, which were thus removed from the analyses together with five items (two words of 3-syllables, one pseudo-word of 3-syllables and two pseudo-words of 4-syllables) for which simulated naming latencies were more than two standard deviations of the network mean performance for each experimental condition. A 2 x 2 ANOVA was conducted with Lexicality (words, pseudo-words) and Length (two, three and four syllables) as between-item factors. There was a significant effect of lexicality [F (1,66)=143.79, p<.001], with a mean reaction time difference of 24.58 between words (7.47) and pseudo-words (32.05). More importantly, neither the Lexicality by Length interaction nor the main length effect were significant for either words or pseudo-words [all Fs<1].

As expected, the simulated performance was thus characterised by a strong pseudo-word length effect in reading and the absence of any length effect in lexical decision. However, the network showed an unexpected poor performance on two-syllable pseudo-words in lexical decision. Indeed, 8 of the 20 2-syllable pseudo-words were erroneously recognised as familiar words and accurately named following global processing; six of them had orthographic neighbours. The poor performance of the network on these items therefore primarily reflects its strong generalisation power and questions the validity of the criterion adopted to decide whether the input item was a word or not. A comparison between the input and output orthographic patterns appears as a good indicator since most pseudo-words (except those with lexical orthographic neighbours) are not recognised as familiar items and cannot be read globally (see Ans et al., 1998, for a simulation of the effect of orthographic neighbourhood). Nevertheless, decision might also be based on time to clean up the orthographic output. As shown in Table 3, the orthographic cleaning time (OCT) was on average four times higher for pseudo-words than for words. The 8 erroneously accepted pseudo-words yielded a mean OCT of 51.5 (range: 31.9 – 160.2). It follows that the network's performance would far improve if lexical decision was based on either the comparison between the two input/output orthographic patterns or an OCT cut-off.

General discussion

The aim of this study was to investigate polysyllabic pseudo-word processing through the analysis of length effects in naming and lexical decision. In reading, the ACV98 model (Ans *et al.*, 1998) predicts that familiar words are processed globally whatever their length whereas an analytic sequential procedure applies to pseudo-words. A length effect on naming latency was therefore expected for pseudo-words only. As expected, the analysis of naming latencies (Experiment 1) revealed differential length effects on words and pseudo-words. The participants needed much less time to name two-syllable pseudo-words than three-syllable pseudo-words which in turn were named more quickly than four-syllable pseudo-words. Length effect on naming latency was far stronger for pseudo-words than for words. Nevertheless, results also revealed a slight and unexpected length effect on words, with the participants naming four-syllable words slightly less quickly than three-syllable words. Thus, in apparent contradiction with the ACV98 model's predictions, a slight length effect was found on word naming. It is noteworthy however that this effect was restricted to four-syllable words which extended in angular size from 8 to 10 degrees. Acuity being a decreasing linear function of eccentricity (Anstis, 1974), such angular sizes might go beyond fovea abilities and then cause difficulties to process words in a single glance. It is further noteworthy that similar differences (25 ms vs. 16ms on average) in processing time between 3 and 4 syllable words were found in both reading and lexical decision and that a difference of the same order (29 ms) was found between 3 and 4-syllable pseudo-words in lexical decision, as expected if performance was mainly determined by the item physical properties.

In lexical decision, the absence of length by lexicality interaction on reaction times (Experiment 1) is well in agreement with the model's predictions. The experimental results further show that even if RTs were slightly longer for four than three syllable items, length effect was similar for both types of items, as expected if word and pseudo-word processing relied on the same procedure.

Most results of Experiment 1 -- the Length by Lexicality interaction in reading but not in LD, the Length by Task interaction and the second order Length by Task by Lexicality interaction-- support the claim that two procedures underlie word and pseudo-word reading whereas lexical decision relies on a single procedure whatever the lexicality of the printed item. Results of Experiment 2 further showed that the pseudo-word length effect on online naming latency vanished when naming was delayed. It follows that this length effect cannot be attributed to differences in ease of articulation but rather reflects time needed to generate phonological output, thus the reading procedures themselves.

Simulations conducted on the ACV98 network revealed that the network exhibited a strong Length effect on pseudo-word naming latencies as in normal skilled readers. Simulated data revealed no Length effect on the simulated naming latencies for words, as expected if the extra-time found in humans to process 4 syllable words was mostly due to differences in peripheral visual processing. No length effect was found on either words or pseudo-words in the simulation of lexical decision and the analysis of the simulated data revealed the absence of Length by Lexicality interaction, similarly to the human data.

The overall behavioural results suggest that, contrary to lexical decision, reading relies on two distinct procedures: a global procedure mainly involved in familiar word processing and an analytic sequential procedure involved in pseudo-word reading. Such a view of the reading system is compatible with both the ACV98 model and the DRC model of reading but seems more difficult to reconcile with PDP models which assume that a single global reading procedure applies to all kind of items, be they words or pseudo-words. Simulations previously conducted on letter Length effects but restricted to monosyllabic items (Coltheart et al., 2001) showed that the PSMP model (Plaut et al., 1996) and the ZHB model (Zorzi et al., 1998) yielded no significant interaction between Length and Lexicality, in contrast to the DRC model and contrary to the human data. The present findings further show that the ACV model (Ans et al., 1998) demonstrates an interaction similar to that seen in the human data and is able to simulate polysyllabic items' processing in reading and lexical decision, contrary to its concurrent models.

Appendix A

Practice words:

abri, écran, flèche, écurie, aliment, recette, académie, curiosité, signature, schéma, impôt, cure, garantie, liberté, justice, antiquité, sécurité, avantage.

Practice pseudo-words:

imbri, gacran, cuche, acument, antirie, ariotte, schélituté, écarimie, retiquire, lipôt, justie, flège, égnaté, curanté, acedété, abertavan, sémasire.

Target words:

crédit, parfum, patron, bureau, tennis, palais, tunnel, climat, pigeon, trésor, pouce, terre, presse, guide, type, crampe, pierre, preuve, taille, cause, tabouret, pantalon, comédie, qualité, carnaval, théorie, tribunal, bâtiment, colonie, candidat, panthère, tempête, pelouse, piscine, problème, caniche, guitare, contrôle, caprice, colère, paralysie, proximité, propriété, population, cabriolet, panorama, dispositif, catégorie, priorité, télévision, crocodile, camarade, capitaine, discipline, caractère, caravane, pyramide, conférence, porcelaine, paradoxe.

Target pseudo-words:

pansor, coval, cardit, connis, tétion, direau, promat, cogeon, tupe, proté, pielle, prorre, conche, disfum, pyde, cate, poune, guire, caule, cade, crélidat, patidie, bunatron, guimaret, thépima, bâponnel, prixité, capririe, temprité, pamérie, crolène, piblèce, pretase, quatame, triscire, canorre, pandile, paboure, perane, pitrôsse, parnolasie, palomilais, cliracotif, trécorilet, typuvament, preutésité, tairagolon, talédinal, capêmision, pabriénie, crambudore, telourane, caratède, tenitaice, caférane, caralyce, porolaixe, concevipe, casciplive, pothèrense.

Filler words:

onde, fleuve, chute, genre, chasse, ardeur, humeur, lune, métier, ruban, outil, lapin, chemise, faculté, chocolat, époque, rivière, légume, cinéma, hôpital, incendie, mémoire, escalier, organe, adversaire, entreprise, vestibule, sentinelle, origine, phénomène, éducation, obscurité, économie, intensité, identité, cérémonie.

Filler pseudo-words:

hutier, latil, faban, lémeur, phémie, orté, chote, obre, serve, chade, oure, hône, gencalat, lutimat, méculté, rucental, érilier, métideur, ongune, fleupine, émique, adviėse, cénose, vescate, artenridie, chegaprité, escoménie, iscumoté, ocodention, émoitipin, chupobure, rinésaile, cidugire, intrenelle, enversine, inrénose.

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ABSTRACTS

Through the analysis of length effects (2-to-4 syllables) in reading aloud and lexical decision according to the nature of the items (words or pseudo-words), the present study aimed at investigating the nature of the cognitive procedures specifically involved in polysyllabic pseudo-word processing. The experimental findings revealed a length by lexicality interaction in reading but the absence of such interaction in lexical decision. Furthermore, the strong length effect found on pseudo-words in online naming vanished in delayed naming, so that it can not be interpreted as resulting from articulatory output generation. Similar effects were found through simulations conducted within the multitrace memory model of reading (Ans, Carbonnel & Valdois, 1998) suggesting that pseudo-word reading relies on an analytic procedure which does not apply in either word reading or lexical decision.

A travers l'étude des effets de longueur en lecture et décision lexicale selon la nature des items présentés (mots ou pseudo-mots), cette étude tente d'évaluer la nature des procédures impliquées dans le traitement des pseudo-mots longs. Les résultats expérimentaux montrent, en lecture, l'existence d'une interaction lexicalité x longueur qui n'est pas retrouvée en décision lexicale. De plus, l'effet massif de longueur observé sur les pseudo-mots en lecture immédiate ne peut être dû au processus de génération articulatoire puisque cet effet disparaît en situation de lecture différée. Les simulations effectuées dans le cadre du modèle multitrace de lecture (Ans, Carbonnel & Valdois, 1998) sont largement compatibles avec les résultats expérimentaux suggérant que la lecture des pseudo-mots repose sur une procédure analytique n'intervenant ni en lecture de mots ni en décision lexicale.

INDEX

Keywords: reading, lexical decision, Length effect, Connectionist modelling, Simulations

AUTHORS

BERNARD ANS

1251, avenue Centrale, BP 47, 38040 GRENOBLE Cedex 9, France

SYLVIANE VALDOIS

alexandra.juphard@univ-savoie.fr